

THE IMMEDIATE EFFECTS OF A TALAR REPOSITIONING TAPING ON ANKLE  
RANGE OF MOTION IN DANCERS

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## ABSTRACT

The purpose of this investigation was to explore the effects of a talar repositioning taping on dorsiflexion and plantarflexion range of motion in dancers. The clinical purpose behind this taping technique is to reduce pain by preventing anterior translation of the talus. Twenty-eight subjects (height:  $166.7 \pm 5.9$ cm; weight:  $61.3 \pm 7.9$ kg; age:  $20.2 \pm 1.5$ years) volunteered for study. All subjects underwent a no tape condition followed by a tape condition. Within each condition, each subject underwent pre and a post-testing range of motion. During the pre and post-test session each subject performed 3 pliés and 3 relevés both in the parallel position and first position. Range of motion was captured and stored with a video camera and then analyzed with Dartfish Pro Suite 6.0. For all subjects, the mean of the three trials, indicated by the highest angle of dorsiflexion and plantarflexion, was used for analysis. Separate repeated measures analysis of variance were used to analyze data for each foot position. For all calculations the alpha level was set at a priori at  $P < .05$ .

Results of the statistical analysis did not reveal a significant change in range of motion for plié in parallel and first positions, or relevé in parallel and first positions with the application of a talar repositioning taping. Specifically, plié in parallel position did not identify a time by tape interaction ( $F_{1,27}=0.7$ ,  $p=0.4$ , power=0.1,  $\eta_p^2=0.03$ ) for dorsiflexion. Plié in first position did not identify a significant time by tape interaction ( $F_{1,27}=0.3$ ,  $p=0.6$ , power= 0.08,  $\eta_p^2=0.01$ ) for dorsiflexion. Relevé in parallel position did not identify a significant time by tape interaction ( $F_{1,27}=0.2$ ,  $p=0.6$ , power= 0.08,  $\eta_p^2=0.01$ ) for plantar flexion. Relevé in first position did not identify a significant time by tape interaction ( $F_{1,27}=1.9$ ,  $p=0.2$ , power= 0.3,  $\eta_p^2=0.07$ ) for plantarflexion. In conclusion, a talar repositioning taping does not significantly affect

plantarflexion or dorsiflexion ranges of motion. Therefore it should not have a significant effect on artistic performance when used.

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## INTRODUCTION

The art of dance places high stress and demands on the ankle. A dancer must be able to withstand the stresses placed on the ankle throughout an increased range of motion when compared to the normal population. The normal population has 10-20°<sup>1-3</sup> of range of motion in ankle dorsiflexion, and a 45-50°<sup>2,3</sup> range in ankle plantarflexion. Conversely, dancers desire 90-100° of plantarflexion to be able to perform proper technique or perfect biomechanical movements involved with the choreography.<sup>4</sup> On average, ballerinas have 76.5° of dorsiflexion and 95.35° of plantarflexion, and modern dancers have 72.2° of dorsiflexion and 105.3° of plantarflexion when measured with a standard goniometer.<sup>5</sup>

The continual training in a plantarflexed position is generally what causes the limitations in dorsiflexion, especially from dancing on pointé and relevé.<sup>4</sup> Dancing in these positions are thought to cause shortened calf musculature which can lead to both limitations in ankle dorsiflexion and injuries to the ankle.<sup>4</sup> Since dancers require such extreme plantarflexion to perform the required movement, the talus can translate anteriorly. This talar movement makes it difficult and painful to dorsiflex the ankle.

Several forms of treatment can be used in an effort to improve dorsiflexion range of motion. The most common include the use of stretching with or without a heat modality,<sup>6-10</sup> or some form of manual therapy.<sup>11-15</sup> Stretching to the gastrocnemius and/or soleus can be combined with ultrasound or diathermy to add a thermal component to the stretch.<sup>6-10</sup> Stretching with an added thermal component has been found to have mixed results depending upon the modality used.<sup>6-10</sup> Diathermy in combination with stretching has been found to be more effective than stretching alone.<sup>10</sup> Ultrasound studies have reported conflicting evidence of

whether ultrasound plus stretching is effective when compared to stretching alone.<sup>6</sup> Static stretching protocols have shown to create increases in dorsiflexion range of motion.<sup>6-10</sup> Manual therapy can include techniques such as traditional joint mobilizations,<sup>13-15</sup> mobilizations with movement,<sup>13</sup> and therapeutic exercise.<sup>12</sup> Both joint mobilizations and mobilizations with movement have been found to have increases in joint range of motion and decreases in pain. Mobilizations with movements have individually been found to produce significant increases in dorsiflexion range of motion.<sup>13, 16</sup>

Clinically several manual therapy methods have been used to treat limitations or restore restrictions in ankle dorsiflexion range of motion. These methods include: mobilizations with movement<sup>13, 14, 16-19</sup> and joint mobilizations.<sup>13-15</sup> Mobilizations with movements have individually been found to produce significant increases in dorsiflexion range of motion.<sup>13, 16</sup> Mobilizations with movement can also be mimicked with repositioning taping techniques such as the fibular repositioning taping.<sup>16-19</sup> The talar repositioning taping, which has been suggested to correct for anatomical faults, can either be used individually or in addition to mobilizations.<sup>17, 18</sup> No research currently exists on this specific treatment technique that repositions the talus within the ankle joint. Therefore, the purpose of this study was to explore the effects of a talar repositioning taping on dorsiflexion and plantarflexion range of motion in dancers.

## METHODS

### **Subjects**

Twenty-nine dancers from the Indiana University Contemporary Dance and Ballet Dance Major Programs volunteered to participate in this study. One subject was excluded from this study due to insufficient time to warm up properly. The total number of dancers used for data analysis was 28 (height: 166.7±5.9cm; weight: 61.3±7.9kg; age: 20.2±1.5years). The experience

of the dancers ranged from 10 to 22 years (mean,  $14.4 \pm 2.7$  years). Subjects were eligible to participate in the study if they were: participating in a combination of at least 3 dance classes and/or at least 10 hours of rehearsal a week. Exclusion criteria included any acute ankle injuries to the test limb in the last six weeks, or surgeries in the last six months. Subjects were tested barefoot throughout the study. All subjects read and signed an informed consent document before participating in the study. Both the consent form and study were approved by Indiana University's Institutional Review Board for the Protection of Human Subjects.

## **Procedures**

All subjects reported to the Athletic Training Research Lab for one testing session. All subjects' underwent two conditions; a no tape condition and a tape condition. The order of test condition was counterbalanced. Before and after each tape condition, closed kinetic chain dorsiflexion and plantarflexion range of motion were measured in both parallel and first positions (Figures 1).

### Range of Motion Measurement

To store and analyze range of motion data, a PC compatible computer (i5-2520M processor, Dell Inc., Round Rock, TX) and Dartfish Pro Suite 6.0 (Dartfish Ltd., Fribourg, Switzerland) was used. The software has been used in previous research as a reliable instrument to measure range of motion.<sup>20</sup> To acquire and store video imaging a camera (Sony Electronics Inc., San Diego, CA) was used. First, four markers were placed on the ankle; the first on the lateral aspect of the knee in line with the joint line, the second on the lateral malleolus, the third on the base of the fifth metatarsal, and the forth on the lateral aspect of the calcaneus<sup>21</sup> (Figure 2).



For closed kinetic chain plantarflexion and dorsiflexion range of motion testing, subjects performed a plié and relevé in two positions. The two foot positions included parallel and first (Figures 3-6). The camera was positioned 4 feet away from the subject's foot and 1.5 foot off the ground, in line with the lateral side of the ankle. A metronome was used throughout the procedure to ensure the dancer was able to keep rhythm. A ballet barre was used to ensure each subject was able to maintain their balance throughout each trial. Three practice trials were allowed prior to the three test trials. To standardize the degree of turnout during first position, two footprints were outlined on a board for the subjects to stand on. The turnout was pre-measured to 145°.

#### Subjective Questionnaires

Subjects completed two questionnaires during the testing period. Following range of motion testing a visual analog scale was used. (Figure 7). The primary researcher asked subjects to, "Rate how painful your ankle is while performing a demi plié," both before and after the application of the tape. Additionally, each subject completed a taping questionnaire which asked subjects specific questions related to how the tape affected their performance. The questionnaire consisted of 5 open ended questions. (Figure 8).

#### Treatment

For the taping condition, the skin was prepped with an alcohol prep pad. A piece of CoverRoll was measured from the posterior lateral malleolus to the posterior medial malleolus and then cut. The subject was in the standing position with the midline of the body facing forwards. The subject had a slight bend in the knee with the foot in the neutral weight-bearing position. The strip of CoverRoll was applied taut on the ankle from the posterior border of the

lateral malleolus, around the anterior ankle, to the posterior border of the medial malleolus, and centered over the joint line. The first strip of Leukotape was measured by placing the non-adhesive side of the tape from the anterior border of the lateral malleolus to the anterior border of the medial malleolus (Figure 9). Once this was measured, the strip was cut. To apply the strip of tape, one edge of the tape was placed on the midline of the lateral malleolus and then the examiner placed the left hand (for the right ankle) over it to ensure that the tape stayed when it was pulled taut. Next, the subject lunged forward as far as they could without having their heel come off of the ground. While the subject was lunging forward, the examiner began pulling the tape to follow the path of the CoverRoll, anteriorly towards the medial malleolus. Once the subject had completed the lunge, the tape was pulled tight with a medial force with the right hand while keeping the other end of the tape in place with the left hand. A second strip of tape was then applied following the same protocol as the first.

### **Statistical Analysis**

In order to standardize the range of motion measurements, starting and ending positions were determined for each subject for each trial. The starting position was determined by the angle (in degrees) while the subject was standing in a resting position. The ending position was determined by the maximal movement of each trial (for dorsiflexion, the lowest measurement was used, and for plantarflexion the highest measurement was used). The angle was then calculated by subtracting the starting position from the maximal position for each trial. The mean of the three trials was used for statistical analysis.

Four repeated measures analysis of variance (RMANOVA) were completed, one for each motion (plié in parallel, plié in first, relevé in parallel, relevé in first). Each RMANOVA had two within subject factors (time at two levels: pre and post-test, and group at two levels: tape and

no tape). For all calculations the alpha level was set at a priori at  $P < .05$ . The answers from the post-test taping questionnaires were grouped and coded based on the responses given.

Frequencies were then calculated based on those groups for questions 3, 4, and 5. For example, question 3 was coded based on whether the subject responded increase, decrease, or no change in range of motion. Question 4 was coded based on the answers that could be grouped into positively, negatively, or no change in regards to how the subject felt their performance was affected. Question 5 was coded to include responses from questions 1, 2, and 5 that could be easily grouped together.

## RESULTS

### Plié in Parallel

The results of a repeated measures ANOVA did not identify a time by tape interaction ( $F_{1,27}=0.7$ ,  $p=0.4$ ,  $\text{power}=0.1$ ,  $\eta_p^2=0.03$ ) for dorsiflexion in parallel position. No significant difference was found between the pre and post-test times in the no tape group (mean difference =  $-0.5^\circ \pm 0.7$ , 95% confidence interval, -2.0-1.0,) or in the tape group (mean difference =  $-0.6^\circ \pm 1.0$ , 95% confidence interval, -1.3-2.5,) (Figure 10).

### Plié in First

Interpretation of the RMANOVA did not identify a significant time by tape interaction ( $F_{1,27}=0.3$ ,  $p=0.6$ ,  $\text{power}=0.08$ ,  $\eta_p^2=0.01$ ) for dorsiflexion in first position. No significant difference was found between the pre and post-test times in the no tape group (mean difference =  $1.6^\circ \pm 1.0$ , 95% confidence interval, -0.5-3.8,) or in the tape group (mean difference =  $-0.8^\circ \pm 0.8$ , 95% confidence interval, -0.9- 2.6,) (Figure 11, Table 1).

### Relevé in Parallel

The results of a repeated measures ANOVA did not identify a significant time by tape interaction ( $F_{1,27}=0.2$ ,  $p=0.6$ , power= 0.08,  $\eta_p^2=0.01$ ) for plantarflexion in parallel. No significant difference was found between the pre and post-test times in the no tape group (mean difference= $0.9^\circ \pm 1.3$ , 95% confidence interval, -1.7-3.5,) or in the tape group (mean difference= $-1.7^\circ \pm 1.1$ , 95% confidence interval, -0.6-4.0,) (Figure 12, Table 1).

### Relevé in First

Interpretation of the RMANOVA did not identify a significant time by tape interaction ( $F_{1,27}=1.9$ ,  $p=0.2$ , power= 0.3,  $\eta_p^2=0.07$ ) for plantarflexion in first position. No significant difference was found between the pre and post-test times in the no tape group (mean difference= $0.9^\circ \pm 1.6$ , 95% confidence interval, -2.4-4.2,) or in the tape group (mean difference= $-4.8^\circ \pm 4.1$ , 95% confidence interval, -13.2-3.6,) (Figure 13, Table 1).

### Subjective Questionnaires

The results of this study found that only 2/28 (0.07%) participants were painful, and 7/28 (25%) “felt stuck when they went into dorsiflexion” before the application of the tape. Of those, the 2 who were painful only one “felt stuck”. Twenty-two/28(79.6%) subjects had an overall perceived decrease in range of motion with the tape. Additionally, 17/28(60.7%) subjects had a felt that their performance was affected by the tape. Five out of twenty-eight (17.9%) subjects felt that their performance improved with the tape, 12/28 (42.9%) subjects felt that their performance worsened, and 11/28 (39.3%) just said that they felt their performance was not affected. Seventeen out of 28(60.7%) subjects reported that they felt the tape made their ankle more stable or supportive. Additionally, 15/28 (53.6%) subjects reported that the tape made

them feel more restricted when performing the tasks of the study. Seven out of twenty-eight (25%) subjects described the taping as both restrictive and supportive. Twelve out of twenty-eight (42.9%) people reported some variation of having better form or articulation as a result of the tape, being more aware of body position, and that the tape made them feel like their muscles had to work harder when performing the tasks.

## DISCUSSION

Currently, there is no evidence in the literature pertaining to the effects of a talar repositioning taping on ankle range of motion. To evaluate this topic functionally, we measured plantarflexion during a relevé and dorsiflexion during a pli  . The results of this study indicated that a talar repositioning taping does not appear to affect range of motion in either direction. While the taping did not enhance range of motion it didn't restrict it either

Since there is currently no research to determine the efficacy of a talar repositioning taping, the next closest taping both in theory and use to the talar repositioning taping is the fibular repositioning taping. Despite the lack of scientific support, the fibular repositioning taping is suggested to correct an anterior positional fault of the fibula.<sup>17</sup> Fibular repositioning using non-elastic tape or by manual manipulation is often used clinically as a treatment following ankle sprains.<sup>17</sup> One study used a combination of posterior fibular mobilizations and the fibular repositioning treatment to treat two acute ankle sprains.<sup>16</sup> After the mobilization treatment, the taping was applied to maintain the posterior glide. After a two week period, subjects had immediate reductions in pain, increases in inversion range of motion at the ankle joint, and improved ankle function.<sup>16</sup> Perhaps the fibular taping was found to be successful in increasing

range of motion because it was applied on a symptomatic population. In the current study, only 2/28 (0.07%) were painful, and 7/28 (25%) “felt stuck when they went into dorsiflexion”. Of those, the 2 who were painful only one “felt stuck”. Therefore, it might have been difficult to elicit actual improvements in pain and/or function in the currently tested population.

The range of motion values that were recorded during this study were far less than those previously reported in the dance literature. Most likely it is due to the device used to measure, and/or the procedures used for reporting the values. For example, we chose to standardize all range of motion measures to each person and get exact differences between starting and ending positions instead of just looking at each subject’s terminal position. Most of the dance literature neglects to report how range of motion was captured; was it taken weight bearing, or non-weight bearing, were the measurements standardized to neutral, or what device was used to capture the measurements and what landmarks were used.<sup>4,5</sup> For the purposes of this study we tried to obtain as accurate or true of range of motion values as was possible. Thus we used a 2D motion analysis software and standardized how all measurements were taken.

While it appears that the tape didn’t have any negative or positive effects on range of motion, the post-test taping questionnaire revealed that the subjects perceived changes. For example, the dancers perceived that with the application of two strips of tape they had a decreased range of motion and changes in their performance. If dancers feel that their range of motion is being inhibited, they will be less likely to wear the tape because they will ‘believe’ it will affect their artistic ability to perform to full capacity. Dancers are very aware of their body and even though the results of this study did not identify any effect on range of motion, it still may be hard to convince them to wear any type of taping if they think their range of motion feels decreased. Confoundedly, multiple subjects described the taping as both restrictive but

supportive. One subject went on to clarify, “when I went to relevé I felt resistance going up but at the same time I felt support that I wasn’t going to roll my ankle”.

The results of this study are only applicable to the performing arts, more specifically, contemporary dance, modern dance, and ballet. The specific movement tasks that were tested in this study are consistent with everyday tasks that one would find in the aforementioned types of dance. Since the results of this study did not identify differences in actual range of motion based on tape condition, clinicians now have the evidence to show that this particular technique will not hinder actual range of motion.

### **Limitations**

The purpose of this study was to explore the effects of a talar repositioning taping on dorsiflexion and plantarflexion range of motion in dancers. However, some limitations of this study must be addressed. First, the study only investigated the immediate effects of a talar repositioning taping. It did not evaluate the lasting effects. Second, the sample of this study was restricted to females dancers enrolled in a specific ballet or modern (contemporary) major. This restricted the use of both male dancers and dance minors. As a result, the findings cannot be generalized to all dancers. Due to the subjects available, there was an inability to choose based on the presence of pain or symptoms. Having a painful or “symptomatically stuck” sample may have produced different results. Finally, the tape was applied by the same examiner each time; however, the examiner is not able to apply the tape in the exact same way every time.

### **Future Research**

Future research should be geared towards obtaining a symptomatic subject pool, whether that be painful, “stuck”, or both. In future research, it is also important to determine both the

effectiveness of the taping technique, and how long these effects will last. It would be clinically helpful to test the taping on other dance positions or tasks such as jumping, or throughout a class or rehearsal. It may also be beneficial to perform an imaging study (radiograph) with this taping and a symptomatic population. The imaging could help diagnosis an anatomical fault in the symptomatic subjects and then help to determine if the tape corrects for that fault after application. Lastly, the use of this tape in conjunction with other treatments, such as joint mobilizations, manual therapy techniques, or stretching, could provide very clinically relevant information on how to treat an individual who is symptomatic. It could potentially provide alternative treatments to taping outside of the studio.

### **Conclusions**

The results of the study showed that the application of a talar repositioning taping did not statistically alter actual range of motion, even though subjects perceived it to have an effect on range of motion and performance. Additionally, subjects reported the taping as being both supportive and restrictive. Different results may have been identified had it used a symptomatic population. Since the taping did not affect range of motion and used a minimal amount of tape, performers may be more apt to wear it because it should not have a significant effect on artistic performance.



## REFERENCES

1. Tiberio D. Evaluation of Functional Ankle Dorsiflexion Using Subtalar Neutral Position. *Phys Ther.* 1987; 67:955-7.
2. Starkey C, Ryan J. *Evaluation of Orthopedic and Athletic Injuries.* Second ed. Philadelphia: F.A. Davis Company; 2002.
3. Prentice W. *Rehabilitation Techniques for Sports Medicine and Athletic Training.* Fourth ed. New York, NY: McGraw-Hill; 2004.
4. Steinberg N, HersHKovitz I, Peleg S, Dar G, Masharawi Y, Heim M, et al. Range of Joint Movement in Female Dancers and Nondancers Aged 8 to 16 years: Anatomical and Clinical Implications. *Am J Sports Med.* 2006; 34:814-23.
5. Wiesler ER, Hunter DM, Martin DF, Curl WW, Hoen H. Ankle Flexibility and Injury Patterns in Dancers. *Am J Sports Med.* 1996; 24:754-7.
6. Tabrizi P, McIntyre W, Quesnel M, Howard A. Limited Dorsiflexion Predisposes to Injuries of the Ankle in Children. *J Bone Joint Surg.* 2000; 82 B:1103-6.
7. Kadel NJ. Foot and Ankle Injuries in Dance. *Physical medicine and rehabilitation clinics of North America.* 2006; 17:813-26.
8. Macintyre J, Joy E. Foot and Ankle Injuries in Dance *Clin N Sports Med.* 2000; 19:351-68.
9. Ogilvie-Harris D, Mahomed N, Demazière A. Anterior Impingement of the Ankle Treated by Arthroscopic Removal of Bony Spurs. *J Bone Joint Surg.* 1993; 75-B:437-40.
10. Hodgkins CW, Kennedy JG, O'Loughlin PF. Tendon Injuries in Dance. *Clinics in sports medicine.* 2008; 27:279-88.
11. Fujii M, Suzuki D, Uchiyama E, Muraki T, Teramoto A, Aoki M, et al. Does Distal Tibiofibular Joint Mobilization Decrease Limitation of Ankle Dorsiflexion? . *Man Ther.* 2010; 15:117121.
12. Mueller M, Sinacore D, Hastings M, Lott D, Strube M, Johnson J. Impact of Achilles Tendon Lengthening on Functional Limitations and Perceived Disability in People With a Neuropathic Plantar Ulcer. *Diabetes Care.* 2004; 27:1559-64.
13. Munteanu S, Strawhorn A, Landorf K, Bird A, Murley G. A Weightbearing Technique for the Measurement of Ankle Joint Dorsiflexion with the Knee Extended is Reliable. *J Sci Med Sport.* 2009; 12:54-9.
14. Johanson M, Baer J, Hovermale H, Phouthavong P. Subtalar Joint Position During Gastrocnemius Stretching and Ankle Dorsiflexion Range of Motion. *J Athl Train.* 2008; 43:172-8.
15. Reid A, Birmingham T, Alcock G. Efficacy of Mobilization with Movement for Patients with Limited Dorsiflexion after Ankle Sprain: A Crossover Trial. *Physiotherapy Canada.* 2007; 59:166-72.
16. Van Der Wees P, Lenssen A, Hendricks E, Stomp D, Dekker J, De Bie R. Effectiveness of Exercise Therapy and Manual Mobilisation in Acute Ankle Sprain and Functional Instability: A Systemic Review. *Aust J Physiother* 2006; 52:27-37.
17. Draper D, Anderson C, Schulthies S, Ricard M. Immediate and Residual Changes in Dorsiflexion Range of Motion Using an Ultrasound Heat and Stretch Routine. *J Athl Train.* 1998; 33:141-4.
18. Wessling K, DeVane D, Hylton C. Effects of Static Stretch Versus Static Stretch and Ultrasound Combined on Triceps Surae Muscle Extensibility in Healthy Women. *Phys Ther.* 1987; 67:674-9.
19. Bohannon R, Larkin P. Passive Ankle Dorsiflexion Increases in Patients After a Regimen of Tilt Table-Wedge Board Standing. *Phys Ther.* 1985; 65:1676-8.
20. Peres S, Draper D, Knight K, Ricard M. Pulsed Shortwave Diathermy and Prolonged Long-Duration Stretching Increase Dorsiflexion Range of Motion More Than Identical Stretching Without Diathermy. *J Athl Train.* 2002; 37:43-50.
21. Young B, Walker M, Strunce J, Boyles R. A Combined Treatment Approach Emphasizing Impairment-Based Manual Physical Therapy for Plantar Heel Pain: A Case Series. *J Orthop Sports Phys Ther.* 2004; 34:725-33.
22. Dananberg H, Shearstone J, Guillano M. Manipulation Method for the Treatment of Ankle Equinus *J Am Pod Med Assoc.* 2000; 90:385-9.

23. O'Brien T, Vicenzino B. A Study of the Effects of Mulligan's Mobilization with Movement Treatment of Lateral Ankle Pain Using a Case Study Design. *Man Ther.* 1998; 3:78-84.
24. Mulligan B. *Manual Therapy: NAGS, SNAGS, MWMS etc.* 2010.
25. Mulligan B. Mobilisations With Movement (MWM'S). *J Man Manipul Ther.* 1993; 1:154-6.
26. Hetherington B. Lateral Ligament Strains of the Ankle, Do They Exist? *Man Ther.* 1996; 1:274-5.
27. Stensrud S, Mykelbust G, Kristianslund E, Bahr R, Krosshaug T. Correlation Between Two-Dimensional Video Analysis and Subjective Assessment in Evaluating Knee Control Among Elite Female Team Handball Players. *British journal of sports medicine.* 2011; 45:589-95.
28. Lindley T, Kernozek T. Taping and Semirigid Bracing May Not Affect Ankle Functional Range of Motion. *J Athl Train.* 1995; 30:109112.

Table 1: Means and Standard Deviation Range of Motion  
(in degrees) for each Tape Condition and Foot Position

Position/Condition		Plié	Relevé
Parallel	Pre-Test No Tape	26.3±7.5°	54.5± 9.0°
	Post-Test No Tape	24.7±5.6°	53.6±7.9°
	Pre-Test Tape	25.0±5.0°	54.4±9.5°
	Post-Test Tape	24.1±4.5°	52.7±8.6°
First	Pre-Test No Tape	24.6±5.5°	52.9±11.1°
	Post-Test No Tape	25.1±5.9°	52.0±8.9°
	Pre-Test Tape	24.3±6.9°	51.1±9.7°
	Post-Test Tape	23.7±4.1°	55.9±20.4°

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Figure 1: Talar Repositioning Taping Testing Procedures

Figure 2: Landmarks: Lateral Aspect of the Knee in Line with the Joint Line, Lateral Malleolus, Base of the Fifth Metatarsal, and Lateral Aspect of the Calcaneus

Figure 3: Plié in Parallel Position

Figure 4: Plié in First Position

Figure 5: Relevé in Parallel Position

Figure 6: Relevé in First Position

Figure 7: Visual Analog Scale (Pre and Post-Taping)

Figure 8: Post-Test Taping Questionnaire

Figure 9: Talar Repositioning Taping

Figure 10: Mean Range of Motion Scores (degrees)  $\pm$  Standard Deviations for Dorsiflexion Measured in Plié in Parallel Position for Tape vs No Tape Conditions

Figure 11: Mean Range of Motion Scores (degrees)  $\pm$  Standard Deviations for Dorsiflexion Measured in Plié in First Position for Tape vs No Tape Conditions

Figure 12: Mean Range of Motion Scores (degrees)  $\pm$  Standard Deviations for Plantarflexion Measured in Relevé in Parallel Position for Tape vs No Tape Conditions

Figure 13: Mean Range of Motion Scores (degrees)  $\pm$  Standard Deviations for Plantarflexion Measured in Relevé in First Position for Tape vs No Tape Conditions

Figure 1: Talar Repositioning Taping Testing Procedures

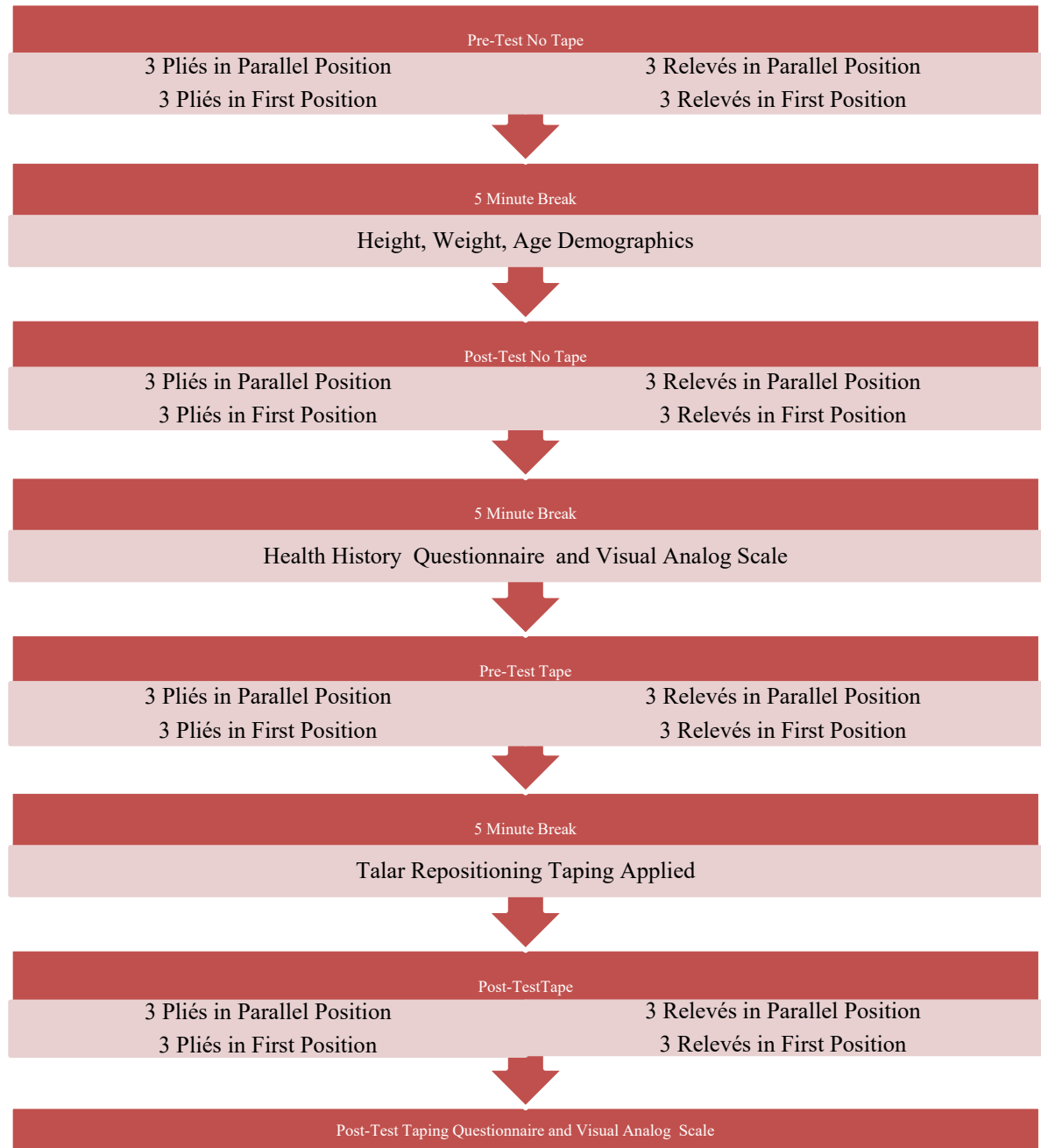


Figure 2: Landmarks: Lateral Aspect of the Knee in Line with the Joint Line, Lateral Malleolus, Base of the Fifth Metatarsal, and Lateral Aspect of the Calcaneus



Figure 3: Plié in Parallel Position

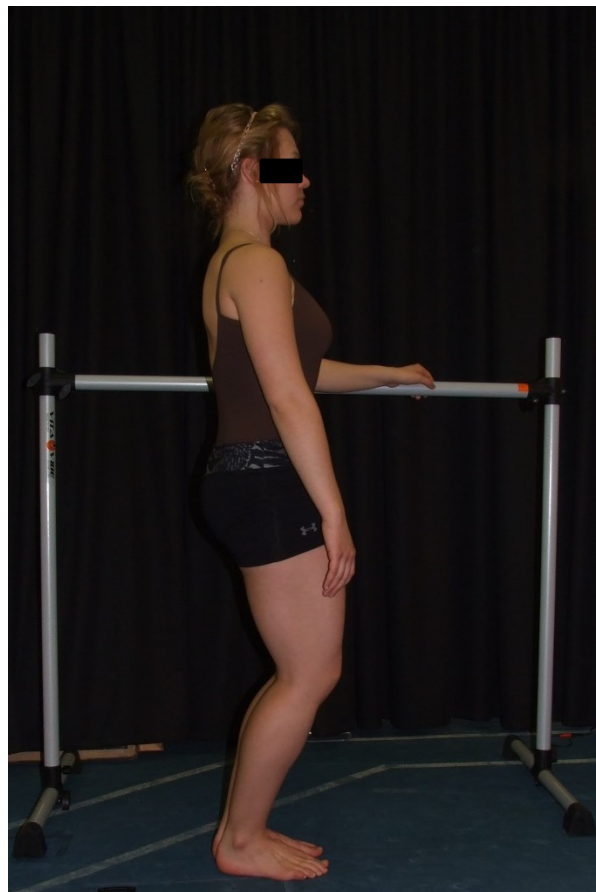


Figure 4: Plié in First Position





Figure 5: Relevé in Parallel Position



Figure 6: Relevé in First Position



Figure 7: Visual Analog Scale (Pre and Post-Taping)

Rate how painful your ankle is while performing a demi plié.

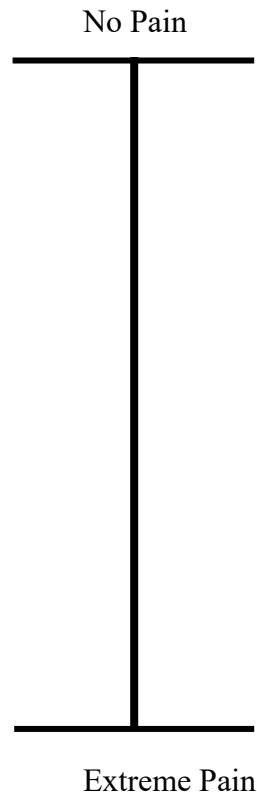


Figure 8: Open Ended Post Taping Questionnaire

Post-test Taping Questionnaire

1. What did you like or not like about the tape?
2. Did you feel a difference when wearing the tape as opposed to not wearing the tape?  
Please provide as much detail as possible.
3. Do you feel like your ankle range of motion was increased or decreased with the use of the tape?
4. Do you feel like your performance was affected by the use of the tape? Please describe in what ways you felt your performance was affected.
5. Please provide any additional information about your feelings of the tape.

Figure 9: Talar Repositioning Taping



Figure 10: Mean Range of Motion Scores (degrees)  $\pm$  Standard Deviations for Dorsiflexion Measured in Plié in Parallel Position for Tape vs No Tape Conditions

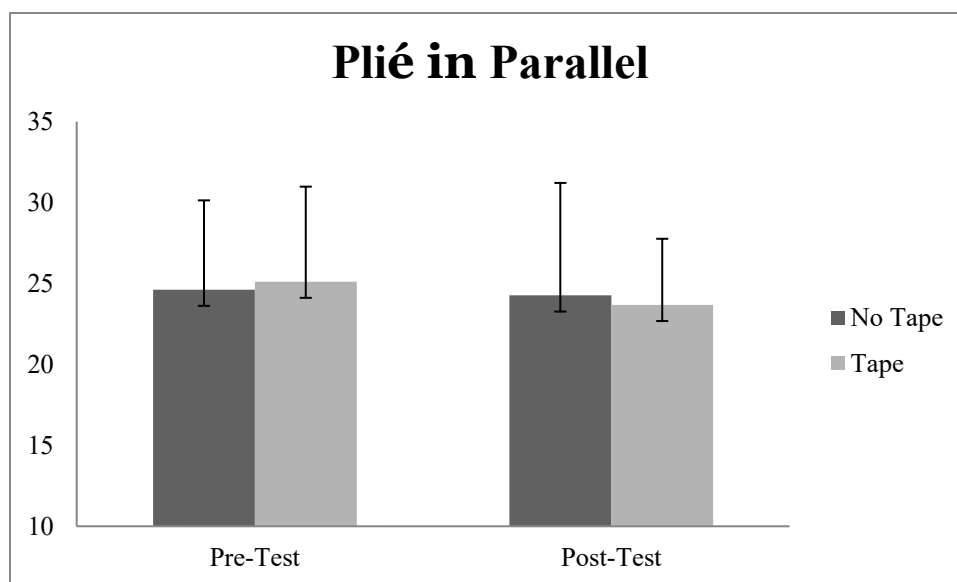


Figure 11: Mean Range of Motion Scores (degrees)  $\pm$  Standard Deviations for Dorsiflexion Measured in Plié in First Position for Tape vs No Tape Conditions

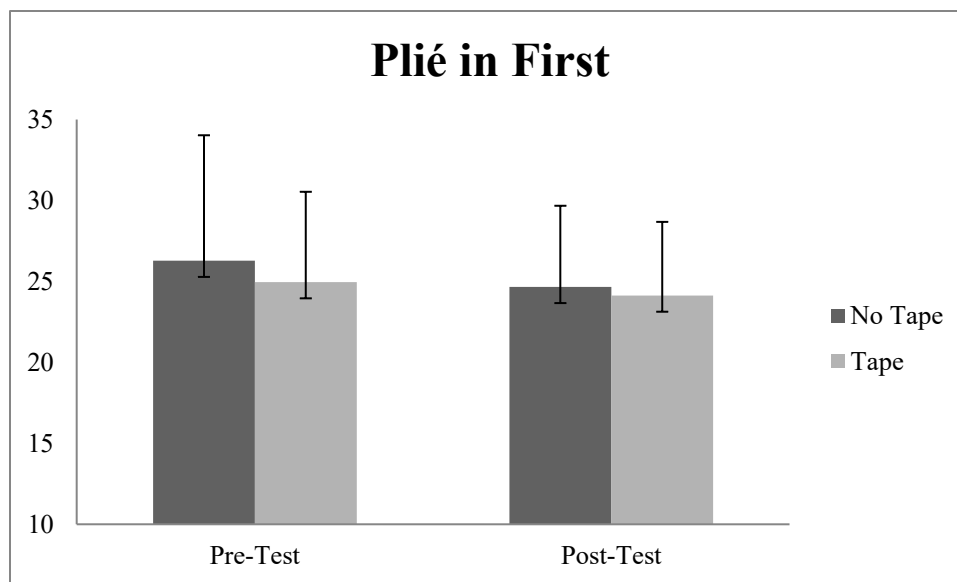


Figure 12: Mean Range of Motion Scores (degrees)  $\pm$  Standard Deviations for Plantarflexion Measured in Relevé in Parallel Position for Tape vs No Tape Conditions

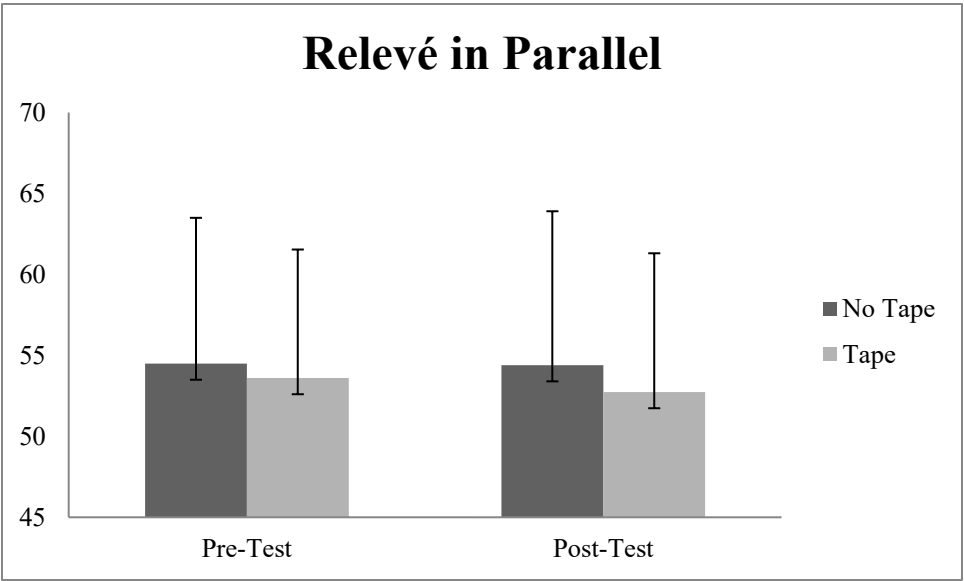
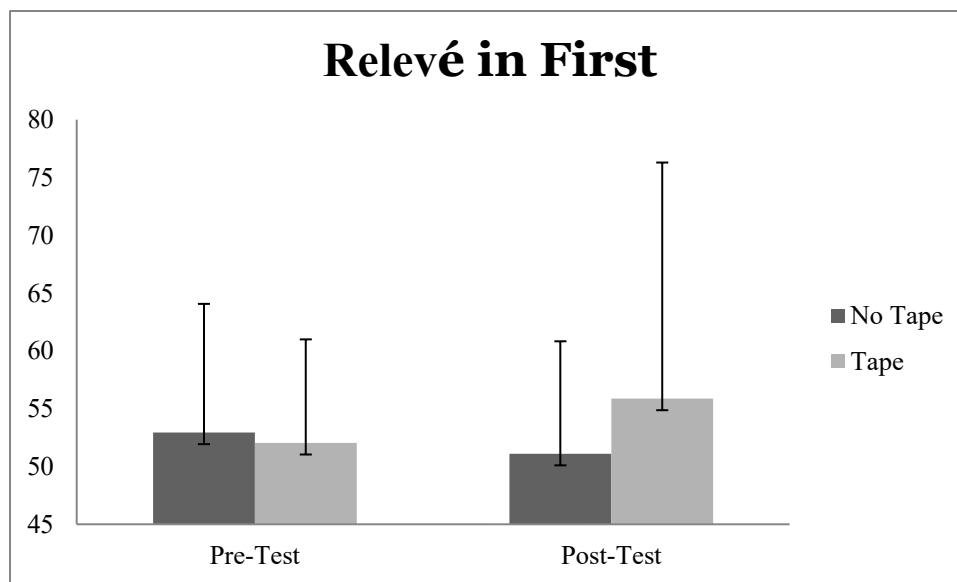




Figure 13: Mean Range of Motion Scores (degrees)  $\pm$  Standard Deviations for Plantarflexion Measured in Relevé in First Position for Tape vs No Tape Conditions



## APPENDICES

## **APPENDIX A**

Operational definitions

Assumptions

Delimitations

Limitations

Statement of the Problem

Independent Variables

Dependent Variables

Research Hypothesis

## APPENDIX A

### Operational Definitions

Ballet Dancer: an individual currently enrolled in the ballet major at Indiana University, Bloomington.

Contemporary (Modern) Dancer: An individual currently enrolled in the contemporary dance major at Indiana University, Bloomington.

Dancer: An individual currently enrolled in either the ballet or contemporary dance major at Indiana University, Bloomington.

Dartfish: Dartfish (Pro Suite 6.0, Dartfish Ltd., Fribourg, Switzerland) is a computer software that measures degrees of range of motion based off of landmarks on a still frame. The software was used in conjunction with a computer and a camera.

Dorsiflexion: Ankle dorsiflexion is the movement of the foot upwards at the talocrural joint. It was functionally measured while the dancer goes in demi plié.

Experienced Dancer: Dancers had at least 5 years of experience dancing, whether it be with a professional company, or as a novice dancer.

First Position: The standing position with the hips turned out in external rotation and the heels touching.

Parallel Position: The standing position with the midline of the body facing forwards with both feet in parallel to each other, toes facing forward in front of the dancer.

Plantarflexion: Ankle plantarflexion is the movement of the foot downwards at the talocrural joint. It was functionally measured while a dancer goes in relevé.

Plié: A demi plié to the point just before the heels come off the ground. It served as the functional weight-bearing measurement for dorsiflexion.

Practice Trials: Three practice trials were allowed for each task.

Range of Motion Landmarks: The lateral aspect of the knee in line with the joint, base of the fifth digit, the lateral aspect of the calcaneus, and the lateral malleolus will be marked. In Dartfish, a line will be drawn through the marker in the joint line of the knee and the lateral malleolus. Another line will be drawn connecting the markers on the base of the fifth digit and the lateral aspect of the calcaneus. Where the two lines intersect will be the fulcrum of the angle. The angle will then be measured up to the marker in the joint line of the knee and down to the marker on the base of the fifth digit

Relevé: Rising up on the balls of the feet. It served as the functional weight-bearing measurement for plantarflexion.

Talar Repositioning Taping Procedure (TRP): A piece of CoverRoll is placed from the lateral malleolus to the medial malleolus. The first strip of Leukotape is measured by placing the non-adhesive side of the tape from the anterior border of the lateral malleolus to the anterior border of the medial malleolus. Once this was measured the strip was then cut. To apply the strip of tape, one edge of the tape was placed on the midline of the lateral malleolus and then the examiner placed the left hand (for the right ankle) over it to ensure that the tape stayed when pulled taught. Next, the subject lunged forward as far as they could without having their heel come off of the ground. While the subject was lunging forward, the examiner began pulling the tape to follow the path of the CoverRoll, anteriorly towards the medial malleolus. Once the subject had completed the lunge, the tape was pulled tight with a medial force with the right hand while

keeping the other end of the tape in place with the left hand. A second strip of tape was then applied following the same protocol as the first.

### **Assumptions**

The following assumptions applied to this study:

1. The Dartfish software was reliable for measuring range of motion.
2. Subjects were compliant with the investigator's instructions.
3. Subjects were truthful in answering the medical history form.
4. Time of day did not affect the range of motion measurements.
5. The background of ballet dancers was similar to that of contemporary or modern dancers.
6. The background of contemporary or modern dancers was similar to that of ballet dancers.
7. Each dancer demonstrated proper technique for relevé and plié.
8. Dancers had prior formal instruction or basic training in plié and relevé.
9. Subjects filled out the visual analog scale honestly.
10. There was no learning effect for plié or relevé.

### **Delimitations**

The following delimitations applied to this study:

1. All subjects recruited were enrolled in the Indiana University Contemporary Dance or Ballet Major (program).
2. All subjects were between the ages of eighteen and thirty.

3. Only Dartfish was used to measure range of motion.
4. Subjects had no history within the last six weeks of an ankle injury on the side being measured.
5. Subjects had no history of surgery within the last six months.
6. Only the talar repositioning taping was used.
7. The same clinician applied the talar repositioning taping.
8. All subjects had at least 5 years of experience dancing.

### **Limitations**

The following limitations applied to this study:

1. The ability of the examiner to apply the tape in the exact same way every time.
2. Inability to choose subjects based on the presence of pain/symptoms.
3. This study only investigated the immediate effects of the talar repositioning tape.

### **Statement of the Problem**

Dorsiflexion limitations are commonly found among dancers, especially ballet dancers whose bodies have become accustomed to having the talus slide anteriorly to give them greater plantarflexion range of motion.<sup>4</sup> The purpose of this study was to explore the effects of a talar repositioning taping on dorsiflexion and plantarflexion range of motion in dancers. The clinical purpose behind the taping technique is to reduce pain by preventing anterior translation of the talus. In the case of this study, the taping was used to see if it provides an increase in dorsiflexion range of motion, and a hindrance in plantarflexion.

## **Independent Variables**

Two independent variables were evaluated in this study at two levels:

1. Treatment Group
  - a. Leukotape and CoverRoll
  - b. No tape (control)
2. Time
  - a. Pre-test
  - b. Post-test

## **Dependent Variables**

Five dependent variables will be evaluated in this study:

1. Dorsiflexion range of motion (<sup>0</sup>)Plié in Parallel Position
2. Dorsiflexion range of motion (<sup>0</sup>)Plié in First Position
3. Plantarflexion range of motion (<sup>0</sup>) Relevé in First Position
4. Plantarflexion range of motion (<sup>0</sup>) Relevé in Parallel Position
5. Visual Analog Scale (VAS)

## **Research Hypothesis**

1. The tape group's mean range of dorsiflexion (in plié) will be greater than the control group's mean range of dorsiflexion at the post test.
2. The control group's mean range of plantarflexion (in relevé) will be greater than the tape group's mean range of plantarflexion at the post test.



3. The tape group's mean range of dorsiflexion post-test (in pli  ) will be greater than the tape group's mean range of dorsiflexion pre-test.
4. The tape group's mean range of plantarflexion pre-test (in relev  ) will be greater than the tape group's mean range of plantarflexion post-test.
5. The tape group's post-test visual analog scale will be lower than the tape group's pre-test visual analog scale.

### Statistical Hypothesis

- |            |  |
|------------|--|
| 1. Pli     | $H_A: u_C \neq u_{Tape}$ at post test            |
| 2. Relev   | $H_A: u_C \neq u_{Tape}$ at post test            |
| 3. Pli     | $H_A: u_{Pre} \neq u_{Post}$ in the taping group |
| 4. Relev   | $H_A: u_{Pre} \neq u_{Post}$ in the taping group |
| 5. VAS     | $H_A: u_{Pre} \neq u_{Post}$ in the taping group |

### Null Hypothesis

- |            |   |
|------------|---|
| 1. Pli     | $H_A: u_C = u_{Tape}$ at post test            |
| 2. Relev   | $H_A: u_C = u_{Tape}$ at post test            |
| 3. Pli     | $H_A: u_{Pre} = u_{Post}$ in the taping group |
| 4. Relev   | $H_A: u_{Pre} = u_{Post}$ in the taping group |
| 5. VAS     | $H_A: u_{Pre} = u_{Post}$ in the taping group |

## **APPENDIX B**

## REVIEW OF LITERATURE

Both ballet and modern dancers have been historically known for their excessive flexibility and ability to place their bodies into various strenuous positions. As a result, dancers have greater ranges in plantarflexion and dorsiflexion range of motion in the ankle.<sup>4, 5, 22, 23</sup> This increase in range of motion can make the dancer more prone to certain types of injuries or conditions. This review of literature will cover anatomy of the ankle, common dance injuries, ankle range of motion, limitations in dorsiflexion range of motion, range of motion measurement techniques, treatment techniques, dancers and athletic tape and ankle repositioning tapings.

### **Anatomy**

The subtalar joint is located between the superior border of the talus and the inferior border of the calcaneus. The joint has three articular facets, two of which are convex (anterior and middle facets on the talus), and one of which is concave (posterior facet on the talus).<sup>2</sup> A depression allowing for the attachment of an intra-articular ligament, the tarsal canal, crosses the talus and calcaneus. The interosseous talocalcaneal ligament can be found in the tarsal canal and assists in maintaining alignment between the talus and calcaneus. Other supportive collateral ligaments in the area include, ligamentum cervicis, which is found in the lateral tarsal canal, and the medial and lateral bands of the deltoid ligament.<sup>2</sup> The posterior talocalcaneal ligament partially restrains anterior glide of the talus on the calcaneus.<sup>2</sup> When weight-bearing, the talus is the moving structure of the glide; when non-weight-bearing the calcaneus glides on the talus.<sup>2</sup>

The talocrural joint is formed by the articulation of the talus, tibia, and the fibula. It has one degree of freedom; plantarflexion and dorsiflexion. There are three ligaments that provide lateral support to the talocrural joint and four ligaments that provide medial support. The anterior talofibular ligament attaches proximally on the anterolateral surface of the lateral malleolus and distally on the talus near the sinus tarsi.<sup>24</sup> The calcaneofibular ligament attaches proximally on the outer portion of the lateral malleolus and distally on the calcaneus<sup>24</sup>. The posterior talofibular ligament attaches proximally on the distal lateral portion of the lateral malleolus, and distally on the talus and calcaneus.<sup>24</sup> The four ligaments that provide medial support and make up the deltoid ligament are as follows: anterior tibiotalar ligament proximally attaching on the anteromedial portion of the malleolus and distally to the superior portion of the medial talus.<sup>2</sup> The posterior tibiotalar ligament attaches on the posterior aspect of the medial malleolus and distally on the posterior aspect of the talus.<sup>2</sup> The tibionavicular ligament attaches from just posterior to the anterior tibiotalar ligament and attaches distally on the medial surface of the navicular.<sup>2</sup> The tibiocalcaneal ligament attaches proximally from the apex of the medial malleolus and attaches distally to the calcaneus directly below.<sup>2</sup>

The anterior compartment of the leg is composed of the anterior tibialis, extensor hallucis longus, extensor digitorum longus, and peroneus (fibularis) tertius. These muscles are the dynamic stabilizers to the ankle. The anterior tibialis is the primary dorsiflexor of the ankle, with the other three muscles aiding in the motion. The posterior compartment is composed of the gastrocnemius, soleus and plantaris. The gastrocnemius and soleus are the primary plantarflexors of the ankle, with the plantaris aiding in the motion. Dynamic support for ankle plantarflexion and dorsiflexion is provided primarily by the tibialis posterior, tibialis anterior, soleus, plantaris, peroneus (fibularis) tertius, and gastrocnemius. It is also assisted by the

extensor digitorum longus, flexor digitorum longus, flexor hallucis longus, peroneus (fibularis) brevis, and peroneus (fibularis) longus.

### **Common Dance Injuries**

It is reported that dancers have an injury rate of 8.4 injuries per 1000 hours performing on stage and 5.1 injuries per 1000 performances.<sup>25</sup> Performing on stage includes time spent in rehearsals and dress rehearsals, in addition to performances. Of these injuries, about 37% resulted in at least one missed performance.<sup>25</sup> The most common injuries reported were located in the foot, ankle, and lower leg, low back, pelvis and neck. Lower extremity injuries accounted for a total of 58% of injuries<sup>26</sup>, and of those injuries reported, 34% (range 23% - 57%) occur in the foot and ankle and 17% (range 0% - 30%) occur in the low back and pelvis.<sup>26</sup> Although the literature states that chronic conditions are seen more often<sup>26-29</sup>, results of previous studies identify that roughly 40-50%<sup>23, 27, 30</sup> of cases are chronic injuries and 40-50% are acute injuries.<sup>23, 27, 30</sup> Examples of common dance injuries can be grouped to include: hallux injuries, ankle impingement syndromes, and tendon injuries.<sup>23, 31, 32</sup>

Since the hallux tendons are involved in plantarflexion and dorsiflexion of the ankle, injury or dysfunction to the hallux can lead to limitation or restrictions in dorsiflexion. Hallux injuries in general can be very disabling to dancers because roughly 80° to 100° of ankle dorsiflexion is required for proper technique when performing relevé onto demi-pointé.<sup>32</sup> Flexor hallucis longus tendinitis or dancer's tendinitis is most commonly seen in female ballet dancers.<sup>31</sup> When a ballet dancer rises into full pointe position, the muscles and tendons crossing the metatarsophalangeal joints have to work roughly three times harder than those crossing only the ankle joint and therefore become at risk for overuse injuries.<sup>32</sup> Inflammation of the tendon arises

from the repetitive change in position from full plantarflexion in pointe to maximal dorsiflexion in plié. Throughout the movements, the tendon is compressed along the postero-medial talus under the sustentaculum tali.<sup>23, 32</sup> Dysfunction of the flexor hallucis longus tendon can produce pain in the area of the tarsal tunnel.<sup>23</sup> The tendon becomes entrapped at several sites along the course of the flexor retinaculum resulting in a stenosing tenosynovitis and can develop into partial longitudinal tears.<sup>23</sup> Dancers with this condition will have pain with dancing in pointe and jumping.

Ankle impingement syndromes can include anterior and posterior impingement. In cases of anterior impingement, there is anterior ankle tenderness with a thickening of the synovium, limited dorsiflexion (for a dancer when compared bilateral) and commonly, palpable osteophytes.<sup>32</sup> With the knee bent, there will be pain with passive ankle dorsiflexion and the dancer may complain of anterior ankle pain with jump landings and a limited range of motion when performing a demi-plié.<sup>32</sup> The mechanism of injury for anterior impingement is usually with a grand plié when the foot and ankle are forced into dorsiflexion.<sup>23, 32</sup> Posterior impingement is caused by compression of the tissues between the calcaneus and the posterior edge of the tibia when the foot is placed in extreme plantar flexion.<sup>32</sup> It may also be a result of the os trigonum<sup>23, 32</sup> which may be acting as a bony block posterior to the talus or a prominent Stieda's process which is the posterior lateral process of the talus.<sup>32</sup>

Although several tendon injuries can occur in dancers, the most commonly noted was Achilles tendon injuries. Achilles tendon pathologies can be caused when dancers force turnout.<sup>23, 32</sup> The forcing of turnout leads to increased pronation of the mid and hind-foot which can put the dancer at risk for these injuries.<sup>32</sup> Shortening of the Achilles tendon can occur due to improper jump landing if the heels do not land on the ground.<sup>32</sup> Additionally, the shortening of

this tendon can lead to decreases or limitations in dorsiflexion range of motion. Other causes of Achilles pathology may include tight heel chords, pronation or rolling in, incomplete relevé, or small or thin tendon mass.<sup>31</sup> Ballet dancers may need to adjust or loosen the ribbons of their point shoes over the tendon area to alleviate irritation.<sup>23, 32</sup>

### **Ankle Range of Motion**

The normal population has an ankle plantarflexion range of 45-50°.<sup>2, 3</sup> The normal population has an ankle dorsiflexion range of 10-20°.<sup>1-3</sup> Dancers desire 90-100° plantarflexion to be able to perform proper technique or perfect biomechanical movements involved with the choreography.<sup>4</sup> On average ballerinas have 76.5° of dorsiflexion and 95.35° of plantarflexion, and modern dancers have 72.2° of dorsiflexion and 105.3° of plantarflexion.<sup>5</sup> The increased range in plantarflexion is necessary when dancing in pointé or relevé.

### **Limitations in Dorsiflexion Range of Motion**

There are several conditions that can cause limitations in dorsiflexion range of motion. The minimum functional amount of dorsiflexion needed for gait is 10° during the toe-off and stance phase; therefore a limitation would be described as a dorsiflexion measurement less than 10°.<sup>1, 33</sup> In the dance population, no information could be found linking a specific number to a limit in dorsiflexion range of motion, for comparison to the general population. However, it has been suggested that insufficient range of ankle motion is a predisposing factor leading to injuries.<sup>23</sup> Conditions affecting the foot locally include: chronic plantar heel pain<sup>11, 34</sup>, forefoot pain<sup>35</sup>, impingement syndrome<sup>23, 32, 36</sup>, forefoot nerve entrapment<sup>34</sup>, plantar fasciitis<sup>7, 35</sup>, ankle fractures<sup>14</sup>, ankle sprains<sup>12-14, 35</sup>, and diabetic ulcerations.<sup>34, 37</sup> Conditions that stem from higher

up the leg include: Achilles tendinopathy <sup>7, 35, 37</sup>, patella tendinopathy <sup>7, 35</sup>, tightness of the triceps surae <sup>35</sup>, shin splints <sup>7</sup>, iliotibial band syndrome <sup>7</sup>, and kinetic chain dysfunctions.<sup>28</sup>

### **Range of Motion Measurement Techniques**

There are several different measurement techniques to quantify dorsiflexion and plantarflexion range of motion in an open and closed kinetic chain position, however, the literature is conflicting on what is best or the most accurate method(s) of measurement. The research is also controversial as to which landmarks to use when performing the measurements.

#### Measurement Instruments

The most commonly used instrument for measuring range of motion is a standard goniometer.<sup>1, 5, 8, 9, 22, 38</sup> The second most commonly used instrument is a digital inclinometer <sup>6, 10, 35</sup>. Other instruments used include a parallelogram electrogoniometer <sup>39</sup>, a clear acrylic plate apparatus <sup>35</sup>, Dynamometer <sup>34</sup>, and Cinematography <sup>38</sup> to name a few. One study compared the use of twenty two different devices in various different techniques to measure dorsiflexion range of motion. The investigators concluded that most of the devices produced consistent results in healthy populations without neurological or stroke comorbidities.<sup>34</sup> This suggests that there is no uniform agreement in the literature as to how dorsiflexion should be measured. The study also concluded that the inconsistency in measurement techniques is most likely due to a lack of standardization in protocols.<sup>34</sup>

#### Computer Software for Range of Motion Analysis

Two-dimensional motion analysis software is available to measure range of motion in a joint. Two commonly used programs are Dartfish (Dartfish Ltd., Fribourg, Switzerland) and



ImageJ (National Institute of Mental Health, Bethesda, MD). Both software have the capability of measuring joint angles from pre-established marked landmarks. Dartfish has the capability of capturing live video footage and going frame by frame to find the desired angle to be measured<sup>20</sup>, whereas ImageJ has to be utilized from a still picture.<sup>40</sup> One study looked at the difference between using the ImageJ software and a standard goniometer when measuring the Q-angle.<sup>41</sup> ImageJ was found to have an ICC value of .98 (SEM=1.05) compared to the ICC value of .96 (SEM=1.02) found with the standard goniometer. The coefficient of variation for ImageJ was found to be 49.16% and the goniometer was 41.41%.<sup>41</sup> The study concluded that ImageJ should be considered a gold standard when calculating angles. Computer-assisted measurement techniques provide rapid comparisons between images, and decreased error by the measurer.<sup>41</sup> A high association was found between the measures of Q-angle obtained with the goniometer when compared to those obtained with the ImageJ program, validating the software.<sup>41</sup> The results of the ICC to determine the degree of consistency of measures taken with the goniometer and ImageJ exceeded .90, which shows the high agreement.<sup>41</sup> The results of the ICC to determine the agreement between measures from the goniometer and measures from ImageJ was .89, which is still considered high.<sup>41</sup>

A day-to-day reliability study was carried out with Dartfish looking at various angles of the knee while completing a series of functional tests such as single leg squats, jumps, and leg vertical drops.<sup>20</sup> Intratester reliability was found to be good with ICC values of .92, .82, and .95. Test-retest reliability was found to be good in the drop jump tests with ICC values of .71, .80, and .90, but only fair and moderate in the single leg squat test with ICC values of .43, and .32.<sup>20</sup> As was indicated by the author, the low values may be due to subject performance more than measurement error, fatigue, or the loose criteria for the study.<sup>20</sup> These low values were found to

be consistent when comparing the 3-D video analysis findings for test-retest reliability to those of the 2-D video.<sup>20</sup> Due to the fact that there was only one measurement collector, intertester reliability could not be tested. Another study concluded that Dartfish software is a valid tool to use to when determining the angle of a moving limb segment.<sup>42</sup> The study analyzed the angle of the elbow in the lead arm of golfers at their peak backswing. The study also concluded that the Dartfish software has good internal consistency, and therefore provides a reliable measure of an angle during a movement. Finally, it was reported that the Dartfish software is a satisfactory means of obtaining range of motion measurements during activity.<sup>42</sup>

### Patient Positioning

When looking at dorsiflexion and plantarflexion range of motion from an open kinetic chain perspective, there has been a discrepancy in the research as to whether the patient should be positioned prone or supine.<sup>1, 8-10, 22</sup> The research does not specify why one position is chosen over the other or whether one of the positions is more reliable. The determining factor when choosing patient positioning appears to be clinician preference, since none of the studies give rationales for why they chose one position, prone or supine, over the other.

When measuring ankle dorsiflexion in the closed kinetic chain position, some variation of the standing lunge was performed. One study discussed five different variations of the original lunge test. Those five variations are, the lunge test with an inclinometer attached to the tibia, with a gravity goniometer, with a goniometer, with a transparent scale on the lateral side of the leg and by measuring the distance from the wall to the big toe.<sup>34</sup> Another study measured weight-bearing dorsiflexion in the following way: the right leg (ankle being measured) is placed behind the left leg as far as possible, while still ensuring that the right knee is fully extended.

The subject places their hands on the wall while they position their tight foot parallel to a line of tape that sits on the floor perpendicular to the wall. The second toe and center of the heel are placed directly over the center of the tape line. The subject leans forward until a maximum stretch is felt in the right posterior leg, while keeping the right knee fully extended and the right heel in full contact with the ground. The left leg is in a comfortable position to maintain balance during the procedure. The angle the right tibia makes to the vertical is measured to get the dorsiflexion range of motion.<sup>35</sup> When looking at measuring ankle plantarflexion in a closed kinetic chain position, only one method was found, which focused on a standing heel-rise test.<sup>39</sup> For this test, the subject stands on one foot. The ipsilateral knee is fully extended and the heel is lifted off of the floor through the maximum range in plantarflexion. The only support the subject is allowed for balance is one light finger touch on an object.<sup>39</sup>

### Landmarks

The landmarks used depended upon the position and instruments and whether the measurement being taken was for dorsiflexion or plantarflexion. Dorsiflexion measurements in the prone and supine position most commonly use the fibular head, lateral malleolus, base of the fifth metatarsal, or fifth metatarsal head as landmarks.<sup>8, 9, 35</sup> Other landmarks include mid-point of the anterior tibial border, between the tibial tuberosity and anterior joint line of the ankle;<sup>35</sup> lateral calf, posterior calf, and heel;<sup>10</sup> the lateral malleolus, head of the fibula, mid-point of the anterior border of the tibia;<sup>35</sup> with a line bisecting the lateral aspect of the lower leg, and a line from the lateral aspect of the calcaneus to the fifth metatarsal head;<sup>1</sup> the lateral aspect of the knee in line with the joint, the lateral malleolus, the lateral aspect of the calcaneus, and the base of the fifth metatarsal;<sup>21</sup> and first metatarsal and midline of the calcaneus, while the heel stays planted on the ground.<sup>13</sup> Plantarflexion measured in the prone position uses the medial malleolus, with

the neutral arm vertical and the measuring arm at the tip of the great toe.<sup>22</sup> Dorsiflexion measurements taken in the standing lunge position use the mid-point of the anterior tibial border, between the tibial tuberosity and anterior joint line of the ankle as the landmarks.<sup>35</sup> A study using 2-D motion analysis software, the heel, and the top of the foot and ankle were tracked.<sup>43</sup> In another study utilizing Dartfish Advanced Analysis Software, ankle range of motion landmarks included the lateral malleolus, tuber calcaneum, and the fifth metatarsophalangeal joint.<sup>44</sup>

### **Treatment Techniques**

There are several techniques for treatment of limited dorsiflexion presented in the literature. Several studies use stretching for increasing dorsiflexion, but vary in their approach. Some studies use the combination of an additional treatment protocol, whereas others used the addition of a modality.<sup>6-9</sup> Manual therapy is another treatment technique that has been mentioned in the literature to increase limitations in dorsiflexion range of motion.<sup>11-16, 18, 19</sup> The effectiveness of each will be discussed below.

Heat modalities such as ultrasound or diathermy can be used in combination with stretching to increase dorsiflexion range of motion.<sup>6, 8, 10</sup> The use of heat coupled with stretching can produce conflicting results. One study compared the use of diathermy plus stretching to just the use of stretching and found that the use of the diathermy was more effective than the stretching alone.<sup>10</sup> Increases in range of motion in the diathermy plus stretching group were averaged to be  $9.8 \pm 3.2^\circ$  beyond neutral whereas the stretching only group had an increase of only  $6.9 \pm 6.9^\circ$  beyond neutral.<sup>10</sup> However, another study looking at the effects of ultrasound and stretching found that although using ultrasound prior to stretching may increase the immediate range of dorsiflexion, the residual increases in dorsiflexion are no different than the

isolated stretching protocol.<sup>6</sup> Greater immediate gains in dorsiflexion range of motion were found in the ultrasound before stretching group. On average, there was found to be an increase of 3° of ankle dorsiflexion in this group.<sup>6</sup> While the stretching protocol by itself was able to produce the same results, it took much longer to obtain the gains in the range of motion. The gains that could be acquired by the ultrasound and stretching group in only one treatment took several treatments to gain in the stretching only group.<sup>6</sup>

According to the literature, static stretching regardless of the technique and duration of stretch, increased dorsiflexion range of motion.<sup>6-10</sup> Examples of different static stretching techniques include standing gastrocnemius lunging stretching<sup>7</sup>, tilt table wedge<sup>9</sup>, and a prone muscle stretching apparatus with a 51 pound load.<sup>8</sup> Duration was another varying factor with studies ranging from 4 repetitions of a 30 second hold with 10 seconds of rest<sup>7</sup>, to 1 repetition of a 7 minute passive hold, and finally to 1 repetition of a 30 minute weight-bearing hold.<sup>9</sup> Each study approached the stretching protocol in a different way but focused specifically on the gastrocnemius. All concluded that stretching created an increase in dorsiflexion range of motion.<sup>6-10</sup> One study utilized a tilt table-wedge board stretching routine and found gains in dorsiflexion ranging from 3-17°.<sup>9</sup> Another study used a stretching apparatus and pulley system and found an increase of about 1.3°<sup>8</sup>, whereas the other one used two static standing calf stretches and found an increase of about 2-3° in dorsiflexion.<sup>6</sup>

The most common manual therapy technique used to increase dorsiflexion range of motion is joint mobilizations. A common joint mobilization technique is Mulligan's mobilizations-with-movement (MWM). The premise behind the technique is thought to be the correction of a positional fault.<sup>17, 18</sup> Once the fault is placed back into the correct position, pain has been found to decrease, and function has been found to increase.<sup>17, 18</sup> Two studies using

MWM, found that there was a significantly greater change in dorsiflexion range of motion following the mobilization<sup>13, 16</sup>, and one found significant increases in inversion.<sup>19</sup> The results of one study suggested that talocrural MWM in patients with limited dorsiflexion due to lateral ankle sprains can provide significant increases in range of motion.<sup>13</sup> Joint mobilizations have been found to not only increase dorsiflexion, but decrease pain, and therefore increase the amount of pain-free range of motion available in the ankle.<sup>13-15</sup>

### **Dancers and Athletic Tape**

Traditionally, athletic tape is used to restrict the end range of motion through either muscle activation<sup>45</sup>, improved proprioceptive awareness<sup>46-48</sup>, or mechanical support via its prophylactic measures.<sup>48</sup> In the dance setting, athletic tape has been used for injuries such as cuboid or subtalar subluxations, muscle strains, and metatarsalgia.<sup>49-51</sup> When applying athletic tape to dancers, special considerations need to be made related to: cosmetic reasons, to allow the dancers to be as functional as possible, and for the safety of the dancers.

Two major issues relating to dancers and athletic tape are compliance and cosmetic appearance. It is necessary to have skin tone or colored tape to be easily hidden by a costume, for performances so that the tape can be easily hidden from the audience.<sup>52</sup> Additionally, if dancers feel that their range of motion is being restricted, may not be as compliant with a taping even if it helps because it will hinder their performance or function. When applying tape of any kind, the technique must be unobtrusive yet practical, to allow the dancer to execute proper technique. In some cases, performance can be immensely hindered by a small restriction in movement. For example, a ballerina's ability to go on pointe may be dramatically compromised by only a few degrees of restricted ankle range of motion.<sup>52</sup> This is one of the reasons why it is

important to use only as much tape as is necessary to achieve the desired result with the dance population. One study concluded that ankle taping holds the foot in a neutral position while the dancer is airborne during jump maneuvers, which is in resistance to the natural tendency to plantarflex and invert.<sup>53</sup> This change in the position of the foot can lead to an increase risk of injury during the dancers landing.<sup>53</sup>

If an ankle strapping is needed for dance activity, a variation of the traditional athletic ankle taping is applied.<sup>52</sup> This variation taping is similar to what is described as a “half and half” ankle taping, however, it allows for much greater range of motion while still providing a level of neurophysiological and mechanical support.<sup>52</sup> This greater range in motion is provided by using less tape in the overall procedure and by substituting the majority of the non-elastic tape for elastic tape.<sup>52</sup> Antipronation tapings are used to manage several lower-extremity injuries and are reported to have immediate pain reduction after application.<sup>54</sup> Low-Dye and High-Dye taping techniques are also often applied in the dance setting to reduce the stress associated with an excessively pronated foot.

Two conditions that often warrant the use of athletic tape in dance are subtalar and cuboid subluxations.<sup>49, 50</sup> Protective taping for subtalar subluxations involves two strands of 2-inch elastic tape that is applied minimally on the midtarsal and ankle joints so that the motion at the ankle is not impaired and the Achilles tendon is not compressed.<sup>50</sup> This taping can allow dancers to return to dancing because it locks the anterior opening of the talonavicular joint into place due to its biomechanical properties.<sup>50</sup> Protective tape used to help maintain the reduction of cuboid subluxations is used to secure a 1/8 inch felt pad beneath the cuboid on the plantar aspect of the foot.<sup>49</sup> This taping uses three pieces of tape; the first begins from the medial aspect of the foot, the second continues from the lateral aspect, and the third secures the first strip to the

second.<sup>49</sup> Although rare, tibialis posterior dysfunction is another condition that warrants a stability taping and has been reported in one professional ballet dancer.<sup>55</sup> The taping method is used as a recovery aid to help support the tibialis posterior and surrounding tissues.<sup>55</sup> There will be a specific point between the head of the fibula and the medial and lateral malleoli where the tibialis posterior will facilitate (the strongest point). Once this location is found, the muscle will be supported with athletic tape in the same position. The tape will be wrapped around the leg at that position one to two times to compress the fibula and tibia together.<sup>55</sup>

### **Ankle Repositioning Tapings**

Repositioning tapings can be used to reduce the risk of injury and correct anatomical faults.<sup>17, 18</sup> Despite the lack of scientific support, the fibular repositioning taping is suggested to correct an anterior positional fault of the fibula.<sup>17</sup> Fibular repositioning using non-elastic tape or by manual manipulation is often used clinically as a treatment following ankle sprains.<sup>17</sup> One study used a combination of posterior fibular mobilizations and the fibular repositioning treatment to treat two acute ankle sprains.<sup>16</sup> After the mobilization treatment, the taping was applied to maintain the posterior glide. After a two week period, both subjects had immediate reductions in pain, increases in inversion range of motion at the ankle joint, and improved ankle function.<sup>16</sup> It has been suggested that the fibular repositioning taping may serve as a protective measure in preventing lateral ankle sprains.<sup>56</sup> This is thought to be done by returning the fibula to its optimal position and preventing anterior displacement.<sup>56</sup>

The fibular repositioning taping may be an acceptable taping technique to use in dance medicine due to its minimal use of tape required (two strips).<sup>16</sup> Currently, no evidence exists that the taping is being used in the dance medicine setting. Since ankle sprains are a common dance



injury<sup>23</sup>, this tape may help to improve or restore a dancer's range of motion, in addition to minimizing their pain. Dancers may also be able to return from a lateral ankle sprain sooner due to the decreased pain and increased range of motion, just like the findings of the aforementioned study.<sup>56</sup> In the study, once the tape was applied post treatment, the subjects were allowed to perform home exercise programs and sport-specific drills.<sup>16</sup> If the tape were to be applied to dancers, they may be able to begin dance- specific tasks sooner than without the tape.

## REFERENCES

1. Tiberio D. Evaluation of Functional Ankle Dorsiflexion Using Subtalar Neutral Position. *Phys Ther.* 1987; 67:955-7.
2. Starkey C, Ryan J. Evaluation of Orthopedic and Athletic Injuries. Second ed. Philadelphia: F.A. Davis Company; 2002.
3. Prentice W. Rehabilitation Techniques for Sports Medicine and Athletic Training. Fourth ed. New York, NY: McGraw-Hill; 2004.
4. Steinberg N, HersHKovitz I, Peleg S, Dar G, Masharawi Y, Heim M, et al. Range of Joint Movement in Female Dancers and Nondancers Aged 8 to 16 years: Anatomical and Clinical Implications. *Am J Sports Med.* 2006; 34:814-23.
5. Wiesler ER, Hunter DM, Martin DF, Curl WW, Hoen H. Ankle Flexibility and Injury Patterns in Dancers. *Am J Sports Med.* 1996; 24:754-7.
6. Draper D, Anderson C, Schulthies S, Ricard M. Immediate and Residual Changes in Dorsiflexion Range of Motion Using an Ultrasound Heat and Stretch Routine. *J Athl Train.* 1998; 33:141-4.
7. Johanson M, Baer J, Hovermale H, Phouthavong P. Subtalar Joint Position During Gastrocnemius Stretching and Ankle Dorsiflexion Range of Motion. *J Athl Train.* 2008; 43:172-8.
8. Wessling K, DeVane D, Hylton C. Effects of Static Stretch Versus Static Stretch and Ultrasound Combined on Triceps Surae Muscle Extensibility in Healthy Women. *Phys Ther.* 1987; 67:674-9.
9. Bohannon R, Larkin P. Passive Ankle Dorsiflexion Increases in Patients After a Regimen of Tilt Table-Wedge Board Standing. *Phys Ther.* 1985; 65:1676-8.
10. Peres S, Draper D, Knight K, Ricard M. Pulsed Shortwave Diathermy and Prolonged Long-Duration Stretching Increase Dorsiflexion Range of Motion More Than Identical Stretching Without Diathermy. *J Athl Train.* 2002; 37:43-50.
11. Young B, Walker M, Strunce J, Boyles R. A Combined Treatment Approach Emphasizing Impairment-Based Manual Physical Therapy for Plantar Heel Pain: A Case Series. *J Orthop Sports Phys Ther.* 2004; 34:725-33.
12. Van Der Wees P, Lenssen A, Hendricks E, Stomp D, Dekker J, De Bie R. Effectiveness of Exercise Therapy and Manual Mobilisation in Acute Ankle Sprain and Functional Instability: A Systemic Review. *Aust J Physiother* 2006; 52:27-37.
13. Reid A, Brirmingham T, Alcock G. Efficacy of Mobilization with Movement for Patients with Limited Dorsiflexion after Ankle Sprain: A Crossover Trial. *Physiotherapy Canada.* 2007; 59:166-72.
14. Fujii M, Suzuki D, Uchiyama E, Muraki T, Teramoto A, Aoki M, et al. Does Distal Tibiofibular Joint Mobilization Decrease Limitation of Ankle Dorsiflexion? . *Man Ther.* 2010; 15:117121.
15. Dananberg H, Shearstone J, Guillano M. Manipulation Method for the Treatment of Ankle Equinus *J Am Pod Med Assoc.* 2000; 90:385-9.
16. O'Brien T, Vicenzino B. A Study of the Effects of Mulligan's Mobilization with Movement Treatment of Lateral Ankle Pain Using a Case Study Design. *Man Ther.* 1998; 3:78-84.
17. Mulligan B. Manual Therapy: NAGS, SNAGS, MWMS etc.2010.
18. Mulligan B. Mobilisations With Movement (MWM'S). *J Man Manipul Ther.* 1993; 1:154-6.
19. Hetherington B. Lateral Ligament Strains of the Ankle, Do They Exist? *Man Ther.* 1996; 1:274-5.
20. Stensrud S, Mykelbust G, Kristianslund E, Bahr R, Krosshaug T. Correlation Between Two-Dimensional Video Analysis and Subjective Assessment in Evaluating Knee Control Among Elite Female Team Handball Players. *British journal of sports medicine.* 2011; 45:589-95.
21. Lindley T, Kernozek T. Taping and Semirigid Bracing May Not Affect Ankle Functional Range of Motion. *J Athl Train.* 1995; 30:109112.

22. Shah S. Determining a Young Dancer's Readiness for Dancing on Pointe. *Cur Sports Med Reports*. 2009; 8:295-9.
23. Macintyre J, Joy E. Foot and Ankle Injuries in Dance *Clin N Sports Med*. 2000; 19:351-68.
24. Hoppenfeld S. *Physical Examination of the Spine & Extremities*. New Jersey: Prentice Hall; 1976.
25. Evans RW, Evans RI, Carvajal S, Perry S. A Survey of Injuries among Broadway Performers. *Am J Pub Health* 1996; 86:77-80.
26. Bronner S, Ojofeimi S, Rose D. Injuries in a Modern Dance Company: Effect of Comprehensive Management on Injury Incidence and Time Loss. *Am J Sports Med*. 2003; 31:365-73.
27. Bowling A. Injuries to Dancers: Prevalence, Treatment, and Perceptions of Causes. *Bri Med J*. 1989; 298:731-4.
28. Macintyre J. Kinetic Chain Dysfunction in Ballet Injuries. *Medical Problems of Performing Artists*. 1994:39-42.
29. Byhring S, Bo K. Musculoskeletal Injuries in the Norwegian National Ballet: A Prospective Cohort Study *Scand J Med Sci Sports*. 2002; 12:365-70.
30. Toledo S, Akuthota V, Drake D, Nadler S, Chou L. Sports and performing arts medicine. 6. issues relating to dancers. *Archives Phys Med Rehab*. 2004; 85:75-8.
31. Hodgkins CW, Kennedy JG, O'Loughlin PF. Tendon Injuries in Dance. *Clinics in sports medicine*. 2008; 27:279-88.
32. Kadel NJ. Foot and Ankle Injuries in Dance. *Physical medicine and rehabilitation clinics of North America*. 2006; 17:813-26.
33. Tabrizi P, McIntyre W, Quesnel M, Howard A. Limited Dorsiflexion Predisposes to Injuries of the Ankle in Children. *J Bone Joint Surg*. 2000; 82 B:1103-6.
34. Gatt A, Chockalingam N. Clinical Assessment of Ankle Joint Dorsiflexion: A Review of Measurement Techniques. *J Am Pod Med Assoc* 2011; 101:59-69.
35. Munteanu S, Strawhorn A, Landorf K, Bird A, Murley G. A Weightbearing Technique for the Measurement of Ankle Joint Dorsiflexion with the Knee Extended is Reliable. *J Sci Med Sport*. 2009; 12:54-9.
36. Ogilvie-Harris D, Mahomed N, Demazière A. Anterior Impingement of the Ankle Treated by Arthroscopic Removal of Bony Spurs. *J Bone Joint Surg*. 1993; 75-B:437-40.
37. Mueller M, Sinacore D, Hastings M, Lott D, Strube M, Johnson J. Impact of Achilles Tendon Lengthening on Functional Limitations and Perceived Disability in People With a Neuropathic Plantar Ulcer. *Diabetes Care*. 2004; 27:1559-64.
38. Gajdosik R, Bohannon R. Clinical Measurement of Range of Motion: Review of Goniometry Emphasizing Reliability and Validity. *Phys Ther*. 1987; 67:1867-72.
39. Lunsford B, Perry J. The Standing Heel-Rise Test for Ankle Plantar Flexion: Criterion for Normal. *Phys Ther*. 1995; 75:694-8 (49-53).
40. Abramoff M, Magalhaes P, Ram S. Image Processing with ImageJ. *Biophotonics Int*. 2004.
41. Roush J, Bustillo K, Low E. Measurement Error Between a Goniometer and the NIH ImageJ Program for Measuring Quadriceps Angle. *Int J Allied Health Sci Practice* 2008; 6:1-6.
42. McKelvey M. Reliability and Validity of a Golf Swing Analysis Software During a Static and a Dynamic Task 2007. p. 63.
43. Frossard L, O'Riordan A, Goodman S. Applied Biomechanics for Evidence-Based Training of Australian Elite Seated Throwers. *Inter Council of Sport Sci and Phy Edu*. 2005:1-12.
44. Squadrone R, Gallozzi C. Biomechanical and Physiological Comparison of Barefoot and Two Shod Conditions in Experienced Barefoot Runners. *J Sport Med Phys Fitness*. 2009; 49:6-13.
45. Lynch S, Eklund U, Gottlieb D, Erenstrom P, Beynnon B. Electromyographic Latency Changes in the Ankle Musculature During Inversion Moments. *Am J Sports Med*. 1996; 24:362-9.

46. Bennell K, Goldie P. The Differential Effects of External Ankle Support on Postural Control J Orthop Sports Phys Ther. 1994; 20:287-95.
47. Robbins S, Waked E, Rappel R. Ankle Taping Improves Proprioception Before and After Exercise in Young men. British journal of sports medicine. 1995; 29:242-7.
48. Cordova M, Ingersoll C, Palmieri R. Efficacy of Prophylactic Ankle Support: An Experimental Perspective J Athl Train. 2002; 37:446-57.
49. Marshall P, Hamilton W. Cuboid Subluxation in Ballet Dancers. Am J Sports Med. 1992; 20:169-75.
50. Menetrey J, Fritschy D. Subtalar Subluxation in Ballet Dancers. Am J Sports Med. 1999; 27:143-9.
51. Petrucci G. Prevention and Management of Dance Injuries. Orthop Nurs. 1993; 12:52-60.
52. Ewalt K. Bandaging and Taping Considerations for the Dancer. J Dance Med Sci. 2010; 14:103-13.
53. Obrascous G. A Rationale for Ankle Taping. J Can Athl Ther Assoc. 1985; 12:19-20.
54. Jamali B, Walker M, Hoke B, Echternach J. Windlass Taping Technique for Symptomatic Relief of Plantar Fasciitis. J Sport Rehabil. 2004; 13:228-43.
55. Gangemi S. Tibialis Posterior Torque and Stability Taping. 2011:1-4.
56. Moiler K, Hall T, Robinson K. The Role of Fibular Tape in the Prevention of Ankle Injury in Basketball: A Pilot Study. J Orthop Sports Phys Ther. 2006; 36:661-8.